Dispersion Measurements at VUV-FEL

FEL R&D Program – Week2 2006

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XFEL Beam Dynamics Meeting, 6 February 2006

Index

- Overview
- How we want to correct
- Measurements and simulations:
  - Difficulties
  - 1st try to correct global trajectory
  - 1st try to correct dispersion
  - Dispersion & orbit response for H8DBC2 and H11DBC2
- Summary / Conclusions
- Next steps

Overview

INTERMEDIATE GOAL
Obtain a dispersion in the undulator smaller than 1 cm in both planes

GOAL of WEEK2
Re-measure dispersion and perform 1st dispersion correction

DIFFICULTIES (week2)
Unstable machine

ACHIEVEMENTS (week2)
- Re-measured dispersion downstream ACC1 & ACC2/3
- First try to correct dispersion & orbit
- Global orbit correction performed
- Dispersion response measured for H8DBC2 & H11DBC2

How we want to correct (I)

We want to correct both orbit and dispersion, using the orbit and dispersion response matrices

- Orbit response term

$$O_{i,j} = \frac{\Delta x_i}{\Delta \theta_j}$$

- Dispersion response term

$$D_{i,j} = \frac{\Delta D_i}{\Delta \theta_j}$$

Δx_i / ΔD_i ---------> change of the orbit / dispersion at the BPM *i*
$\Delta \theta_i$ ---------> change of the kick angle of the steerer *j*

How we want to correct (II)

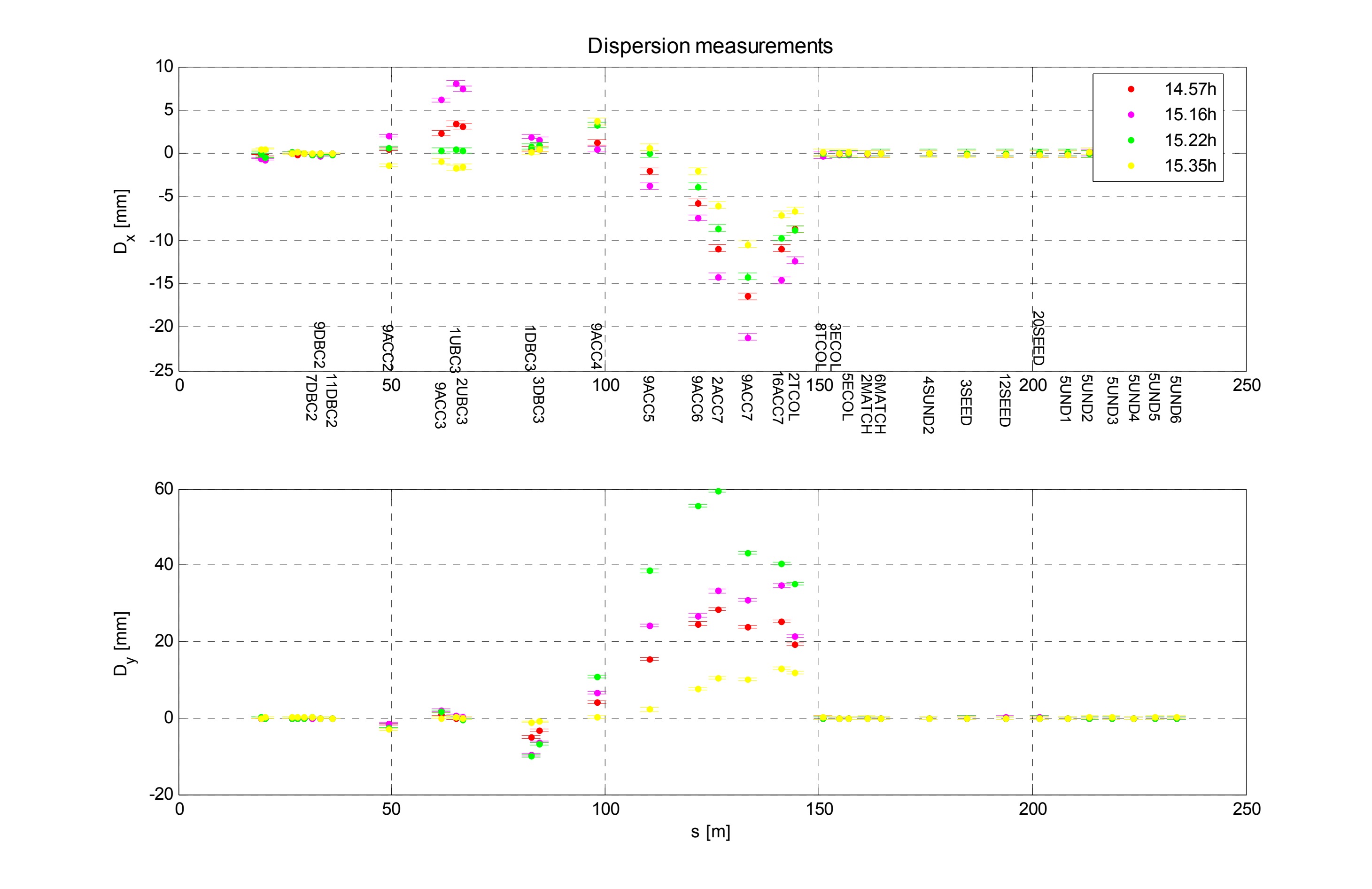
- Required steps:

1. Calculate and/or measure orbit/dispersion response matrices
2. Measure actual orbit/dispersion x_{meas} & d_{meas}
3. Compute corrector strengths
4. Apply corrector currents
5. Repeat 2-3-4 until satisfactory result

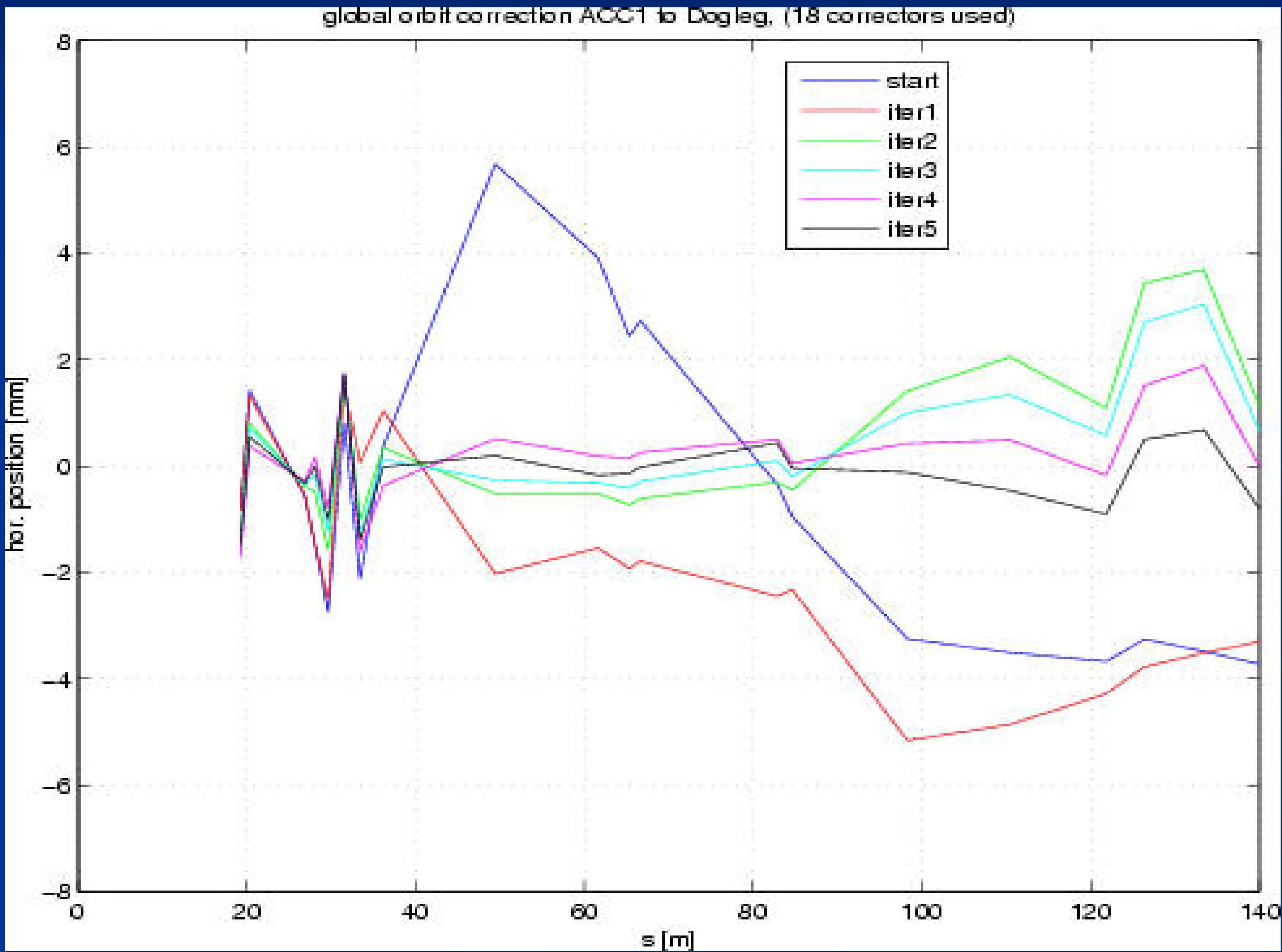
$$\begin{pmatrix} \underline{\underline{O}} \cdot (1-w) \\ \underline{\underline{D}} \cdot w \end{pmatrix} \cdot \underline{\Delta\theta} = \begin{pmatrix} \underline{x} \cdot (1-w) \\ \underline{d} \cdot w \end{pmatrix}$$

$$\sum \left[\begin{pmatrix} \underline{x}_{meas} \\ \underline{d}_{meas} \end{pmatrix} - \begin{pmatrix} \underline{x} \\ \underline{d} \end{pmatrix} \right]^2 = \min \Rightarrow \Delta\underline{\theta}$$

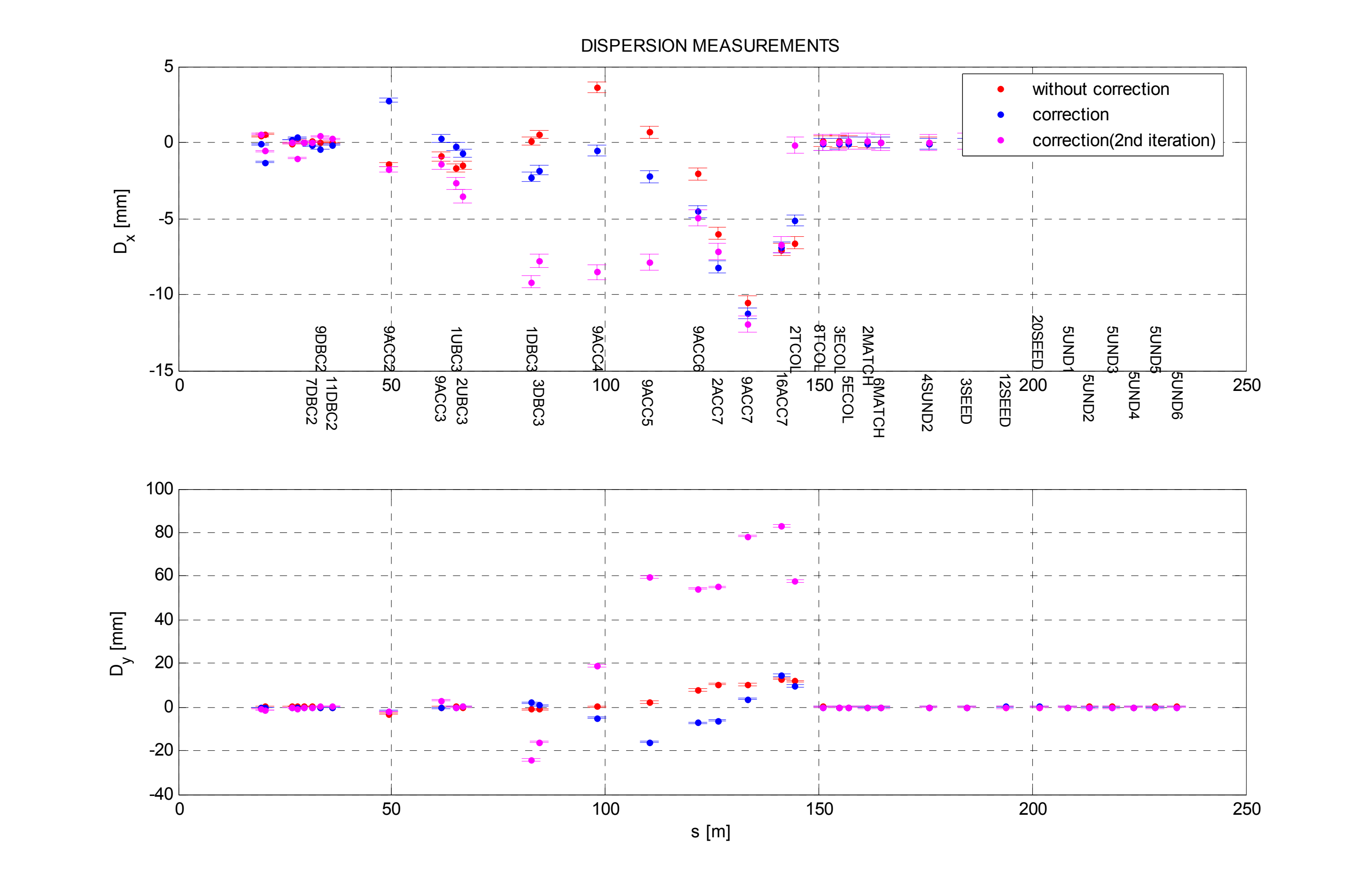
Difficulties: unstable machine



1st try to correct global trajectory ✓



1st try to correct dispersion ✖

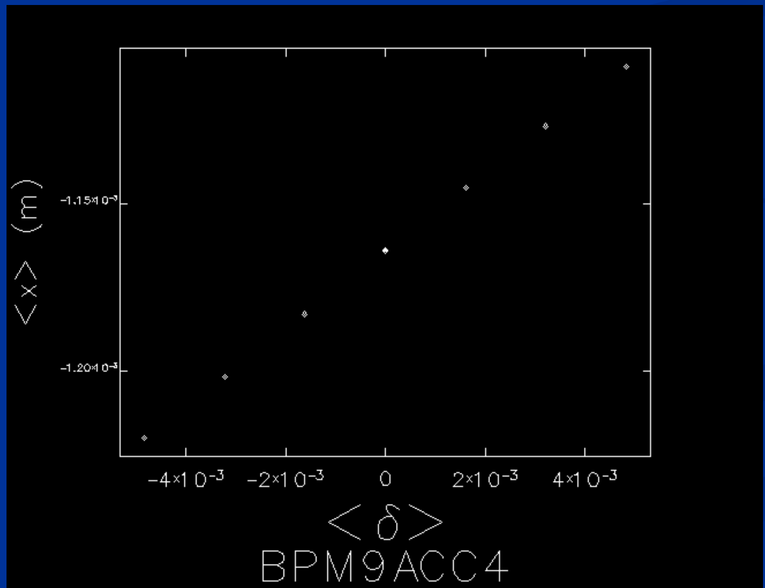


Dispersion response simulations

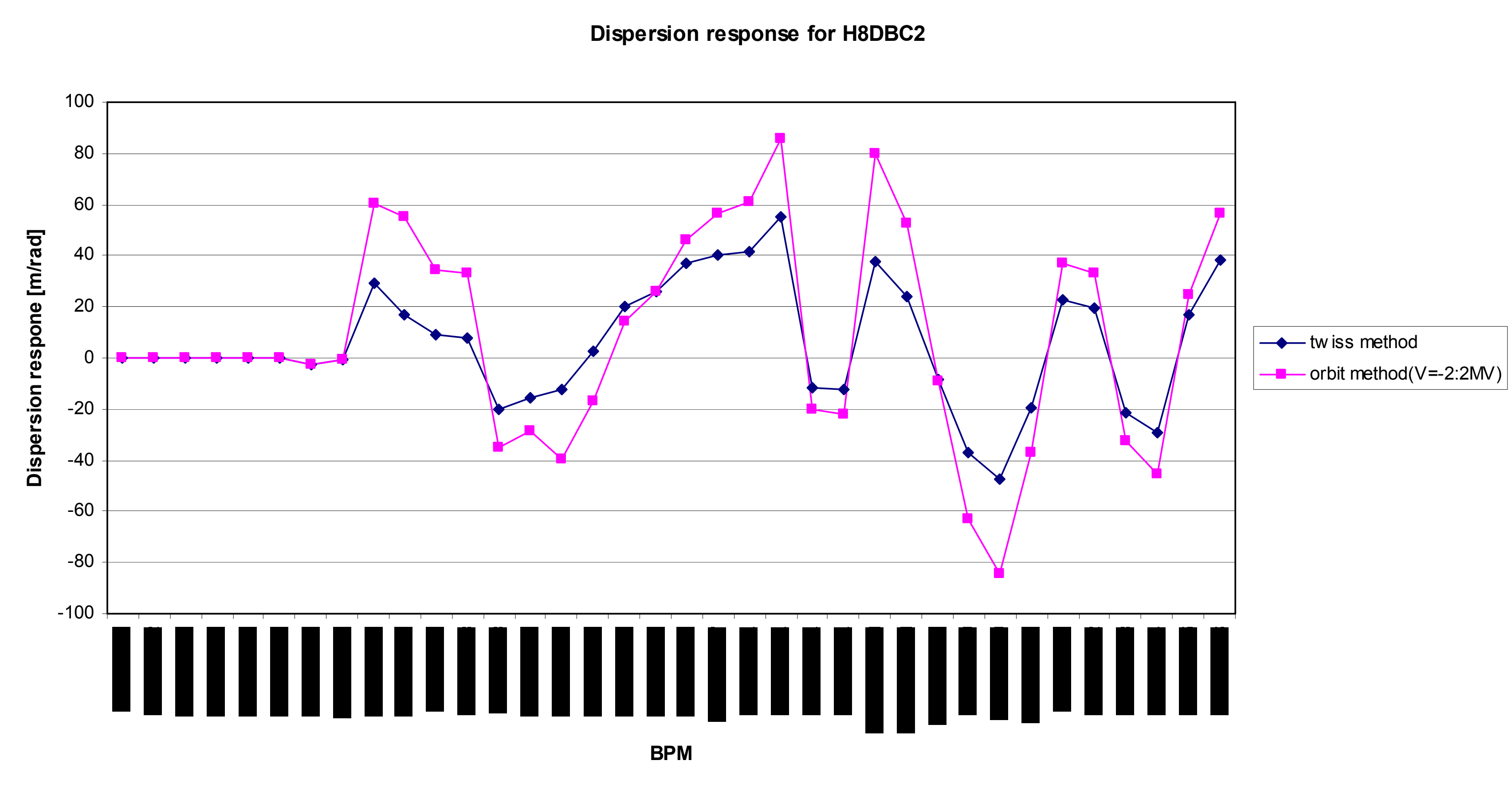
How to calculate the dispersion

- **Twiss method**
  Transport of the beam main parameters through the linac (β, α, γ, μ, D…)

- **Orbit method**
  Track particles for different energies
  Look at the orbit and derive the dispersion

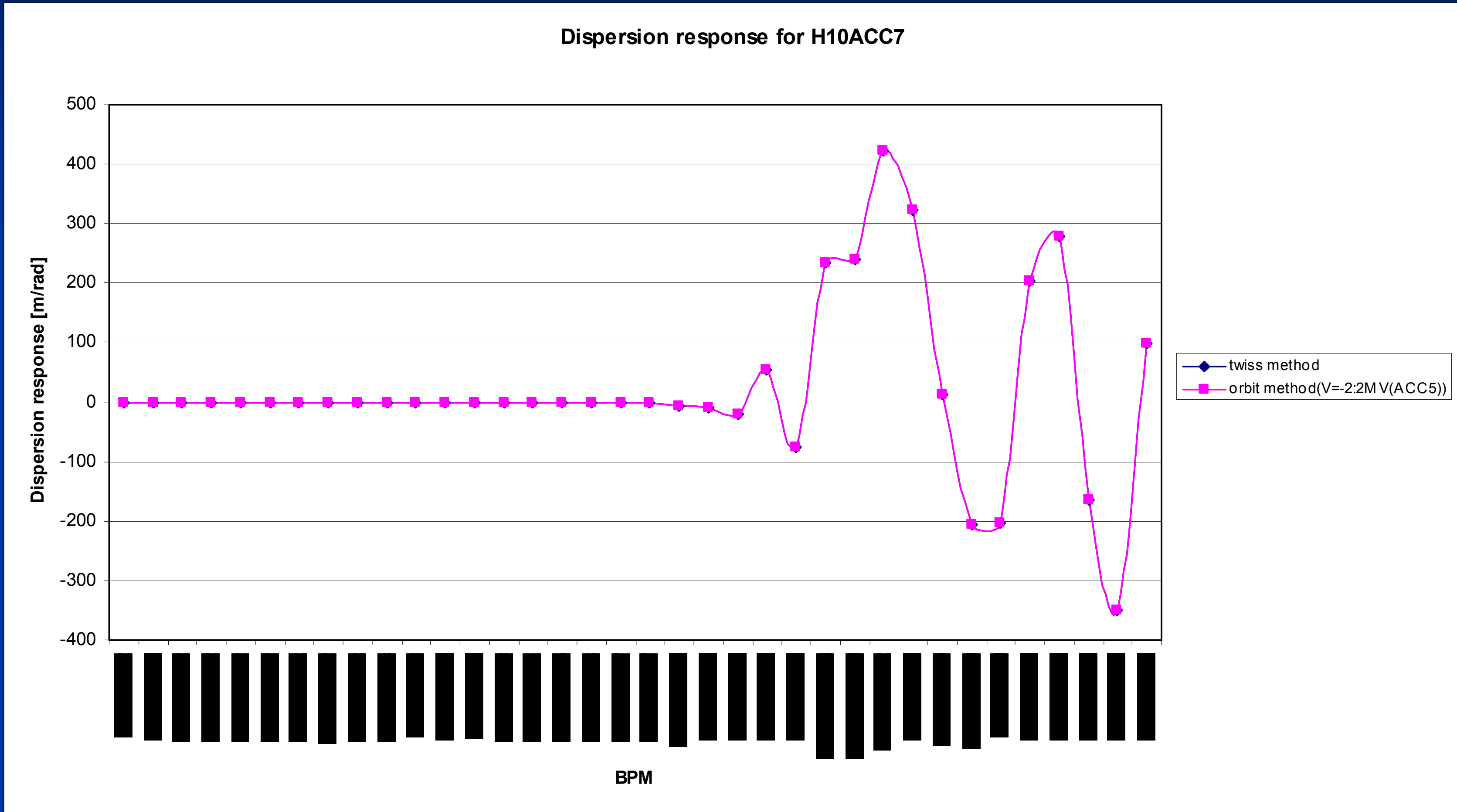


Dispersion response simulations



No agreement if there is an RF cavity downstream the dispersion source

Dispersion response simulations



Agreement if there is NOT an RF cavity downstream the dispersion source

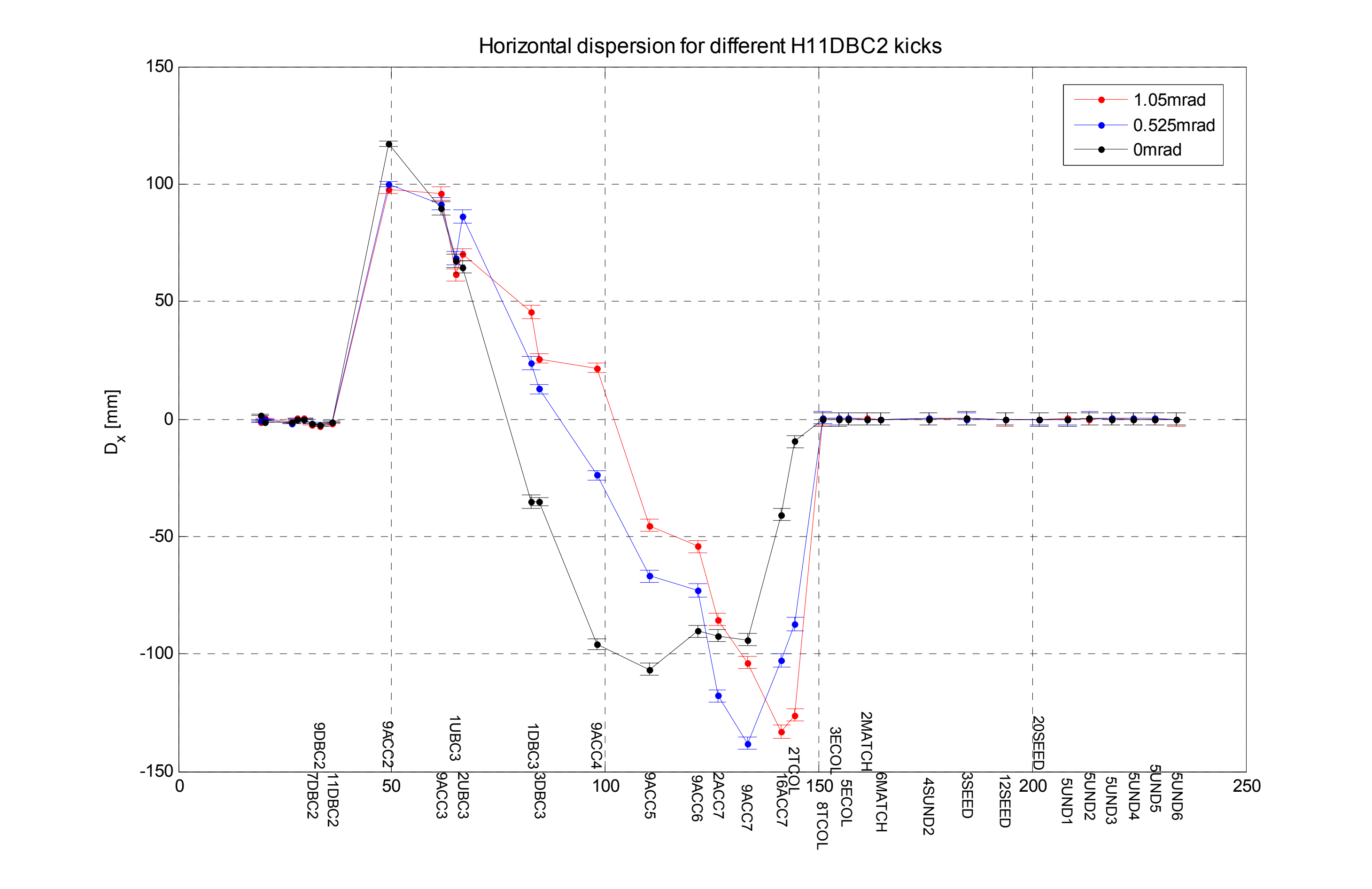
Dispersion response simulations

Why these differences between "Twiss" and "orbit method"?

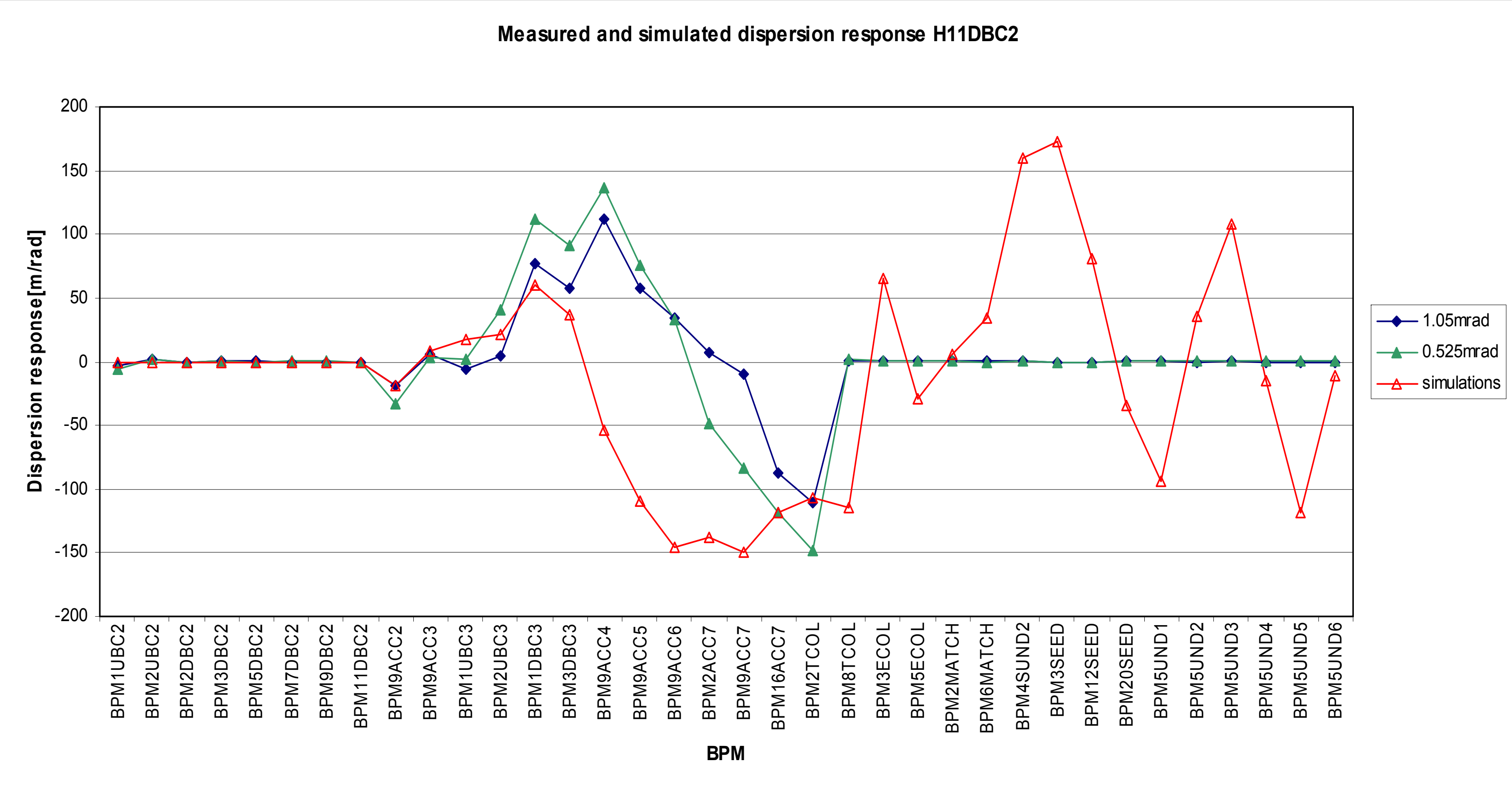
In elegant RF cavities are modeled with a 1st order matrix, therefore the terms of the trajectory are not included in the Twiss calculation

Meanwhile we believe the orbit method results

Dispersion response H11DBC2
measurements



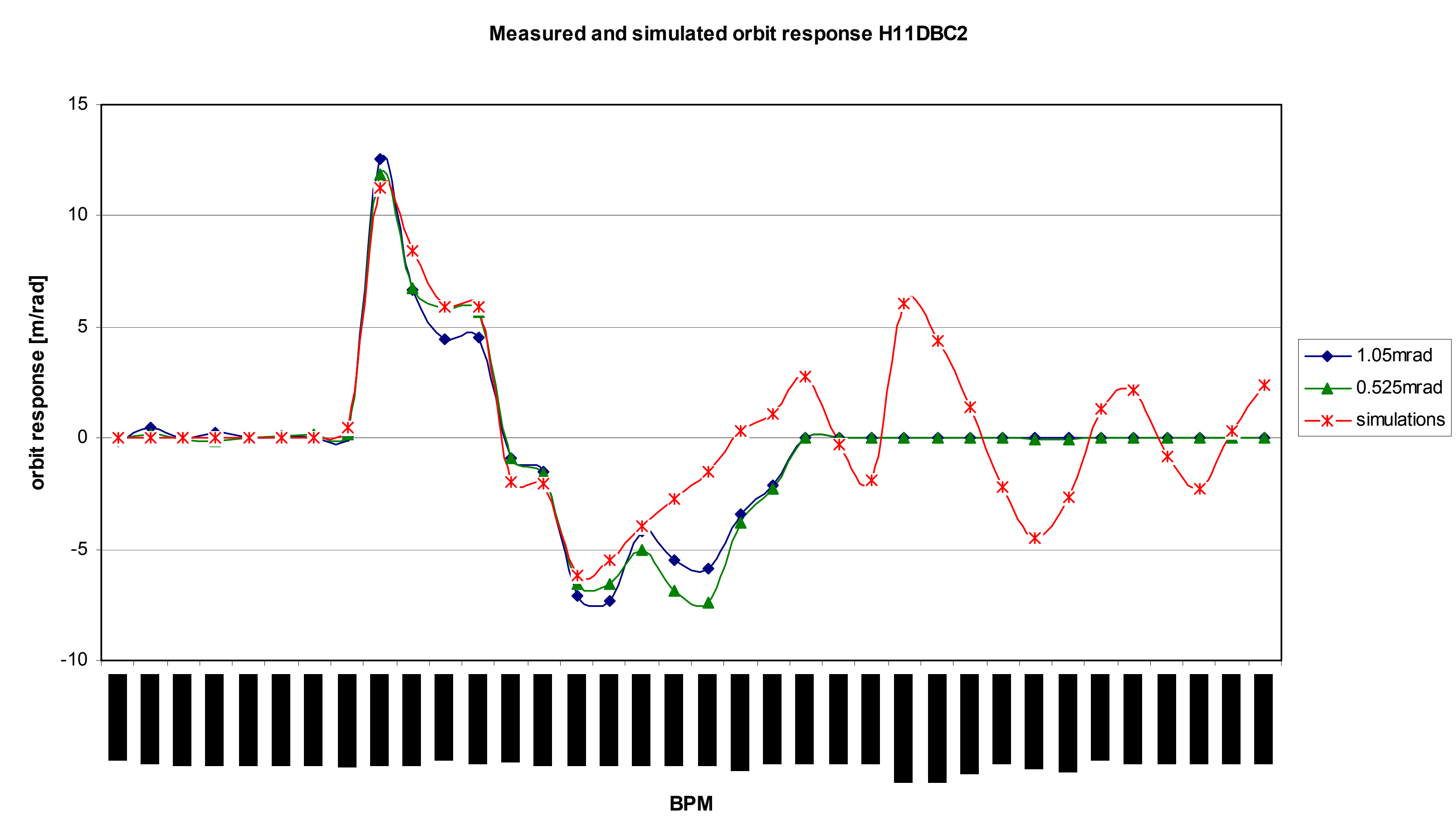
Dispersion response H11DBC2
measurements vs simulations



Ideal model

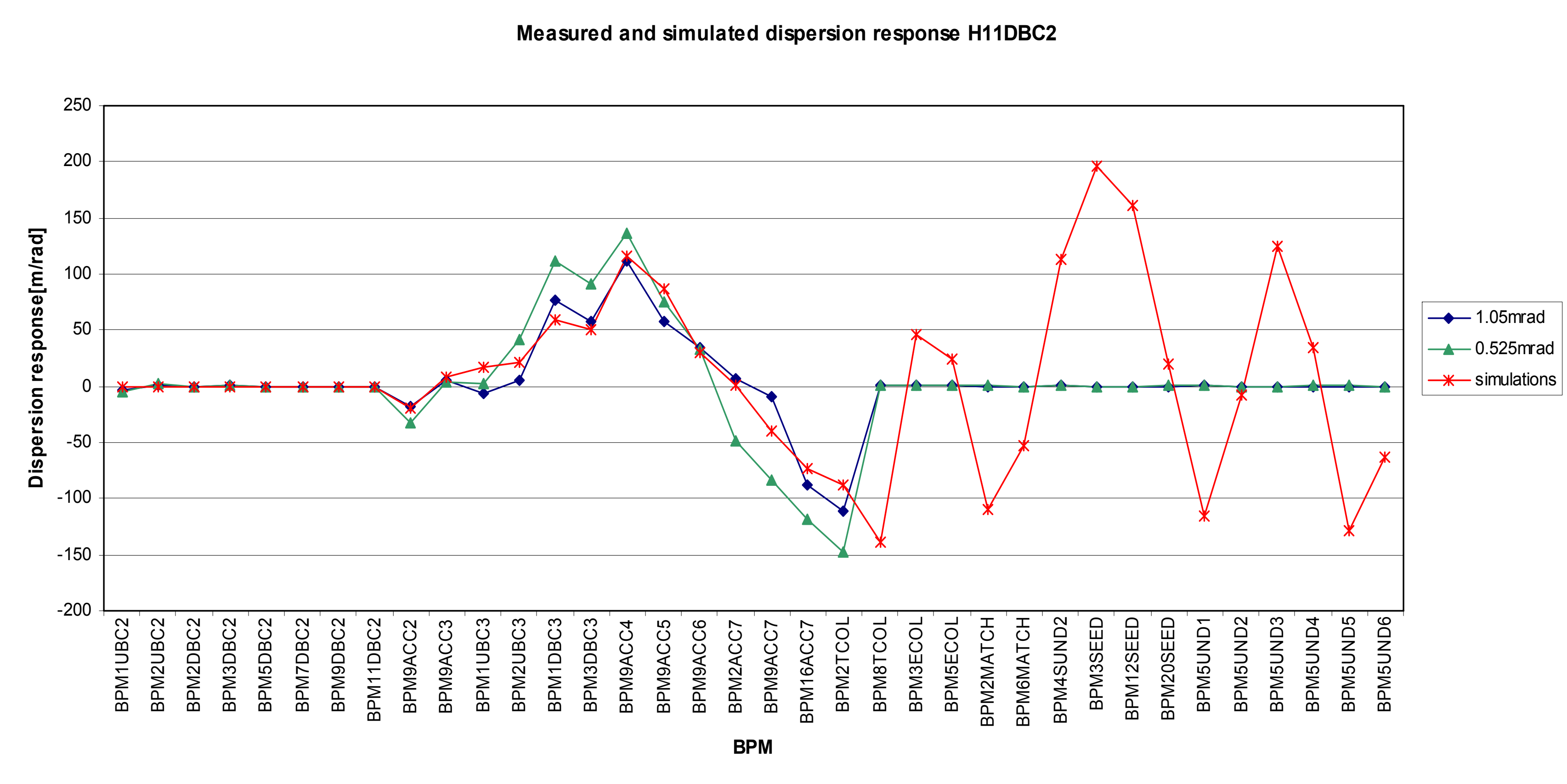
~Agreement

Orbit response H11DBC2
measurements vs simulations



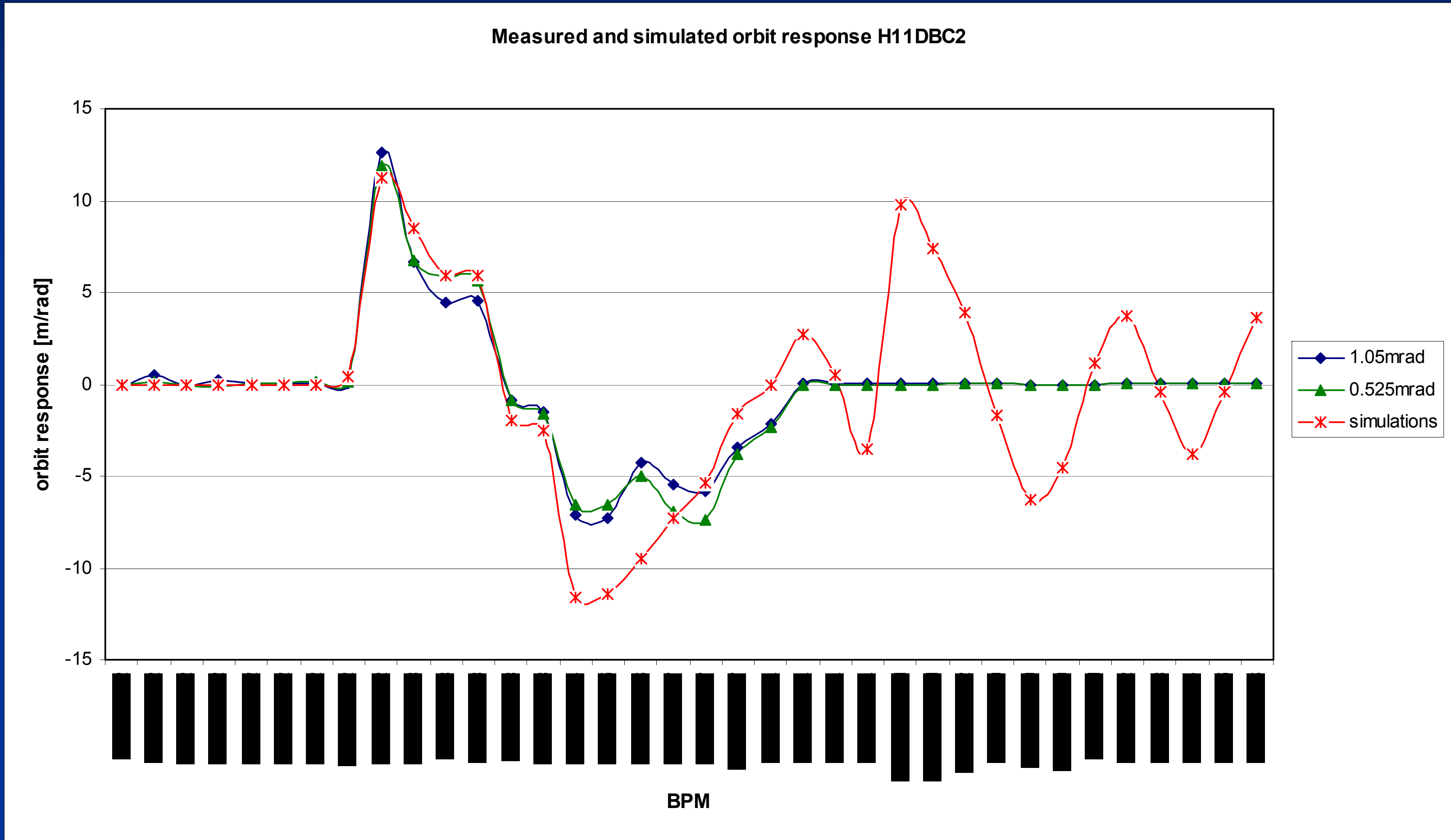
Ideal model
~Agreement

Dispersion response H11DBC2
measurements vs simulations



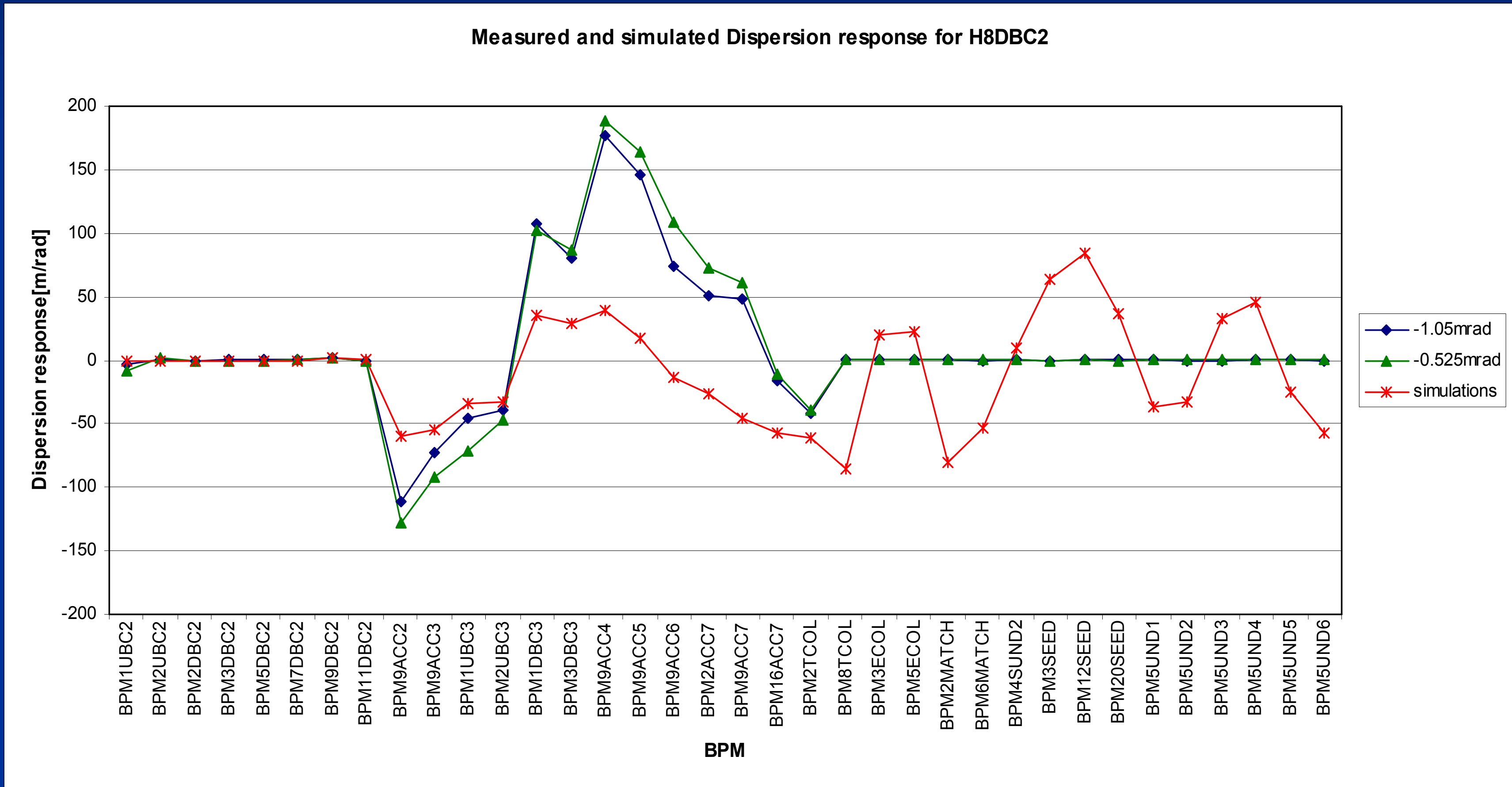
↓Q2DBC3 by 25% or ↑Q3DBC3 by 30% or
↓Q2DBC3 by 15% & ↑Q3DBC3 by 15%
Agreement

Orbit response H11DBC2
measurements vs simulations



↓Q2DBC3 by 25% or ↑Q3DBC3 by 30% or
↓Q2DBC3 by 15% & ↑Q3DBC3 by 15%
~Agreement

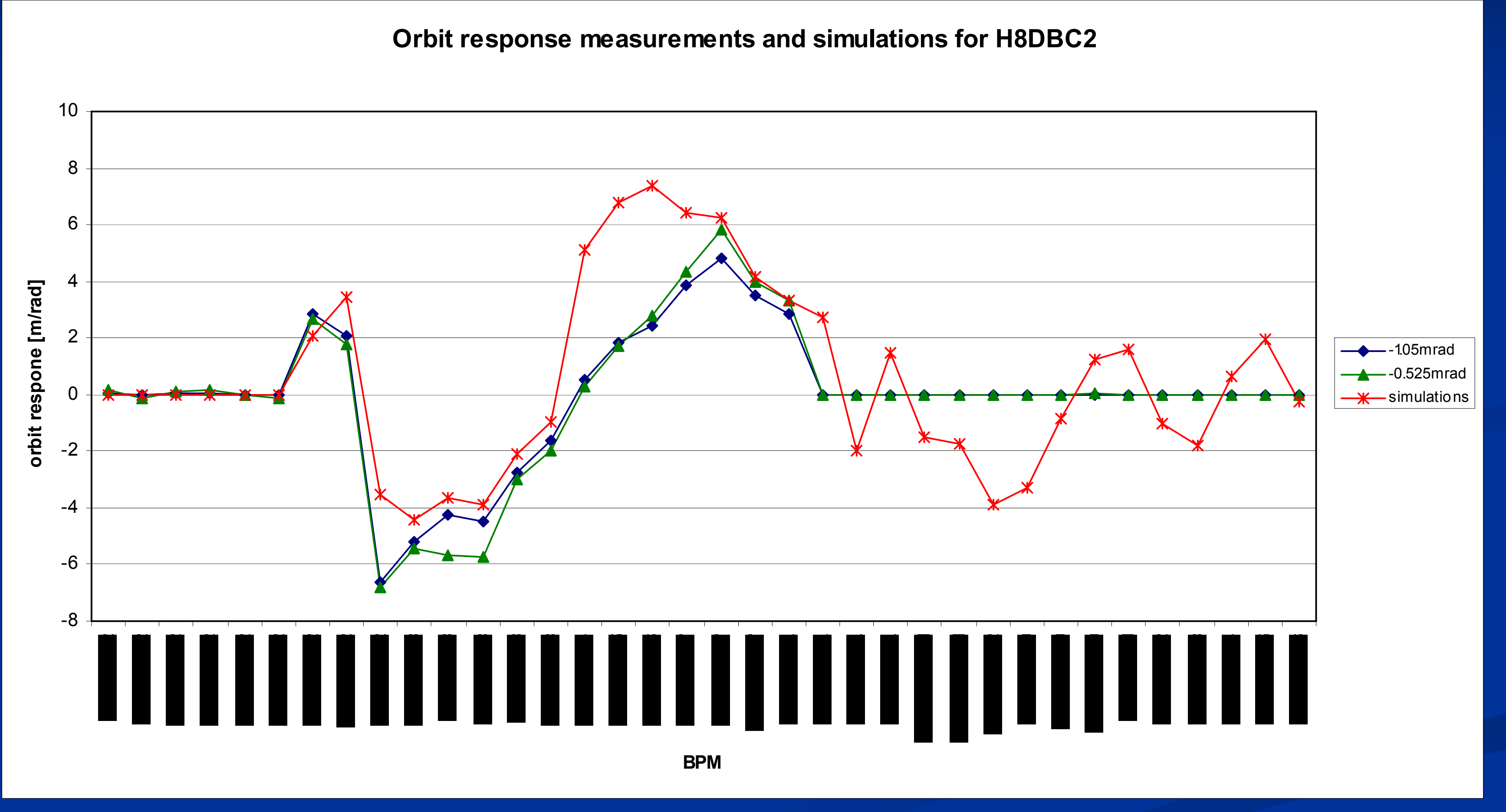
Dispersion response H8DBC2
measurements vs simulations



Ideal model

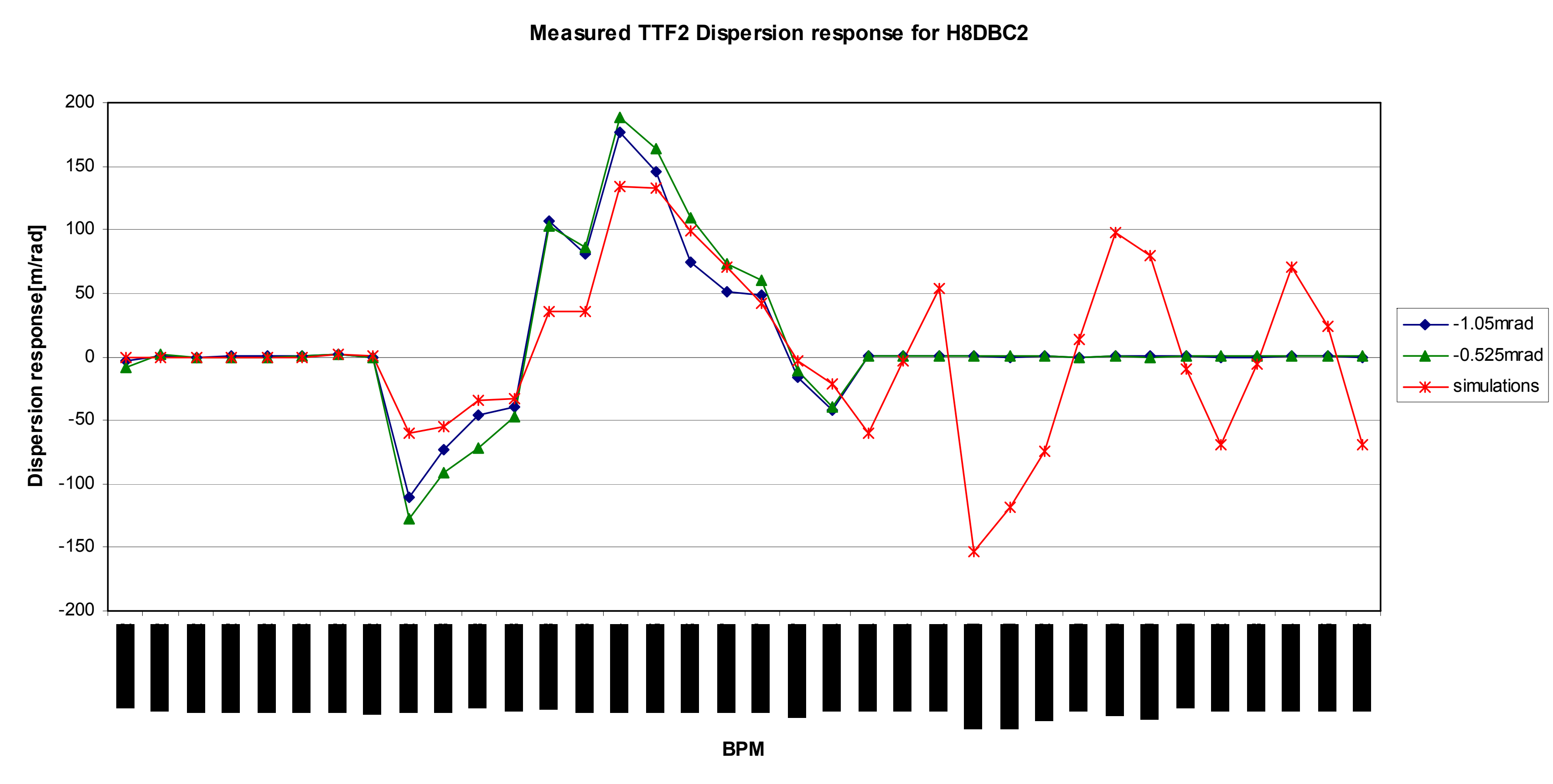
~ Agreement

Orbit response H8DBC2
measurements vs simulations



Ideal model
~ *Agreement*

Dispersion response H8DBC2
measurements vs simulations



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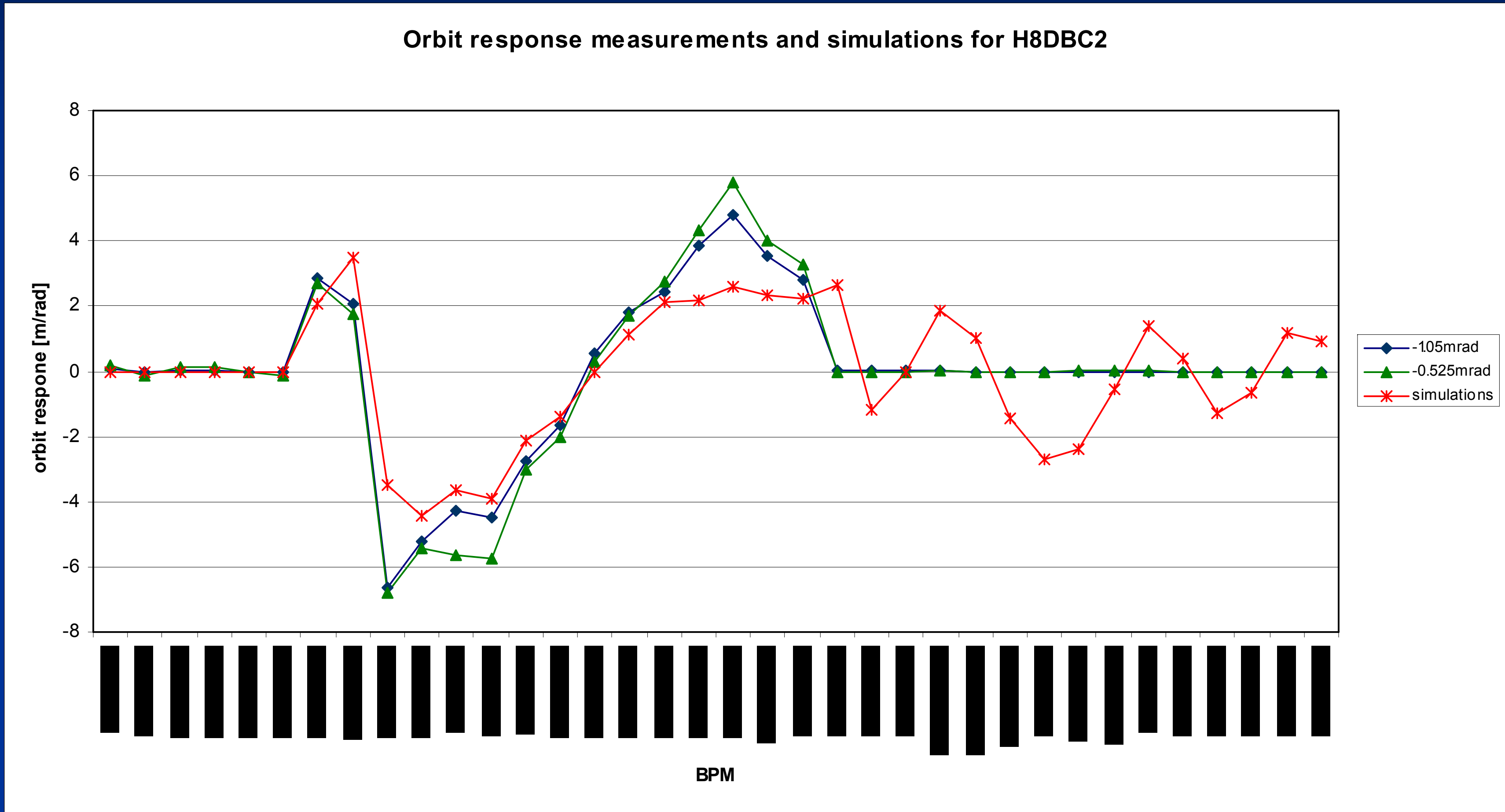
Agreement

Orbit response H8DBC2
measurements vs simulations



↓Q2DBC3 by 25% or ↑Q3DBC3 by 30% or
↓Q2DBC3 by 15% & ↑Q3DBC3 by 15%
Agreement

Summary/conclusions

- 1st try to correct global trajectory with success

- 1st try to correct dispersion without success
  Why? Machine optics ≠ design optics???
  Any other error (energy…)???

- Dispersion measurements need high precision, stability and reproducibility. Therefore measurements are best done within a user run and not after a machine start-up.

- Optics of the machine have to be close to the design optics (or one has to use measured response matrices)

Next Steps

- Simulate global trajectory & dispersion correction (analyze sensitivity to errors)
- Re-measure dispersion response for all steerers (12 hours)
- Either fix optics (off-line) or correct dispersion with measured response matrix (4 hours)

Thank you!